The Importance of the Turbine Model on Coupled Analyses and Overall FOWT Design

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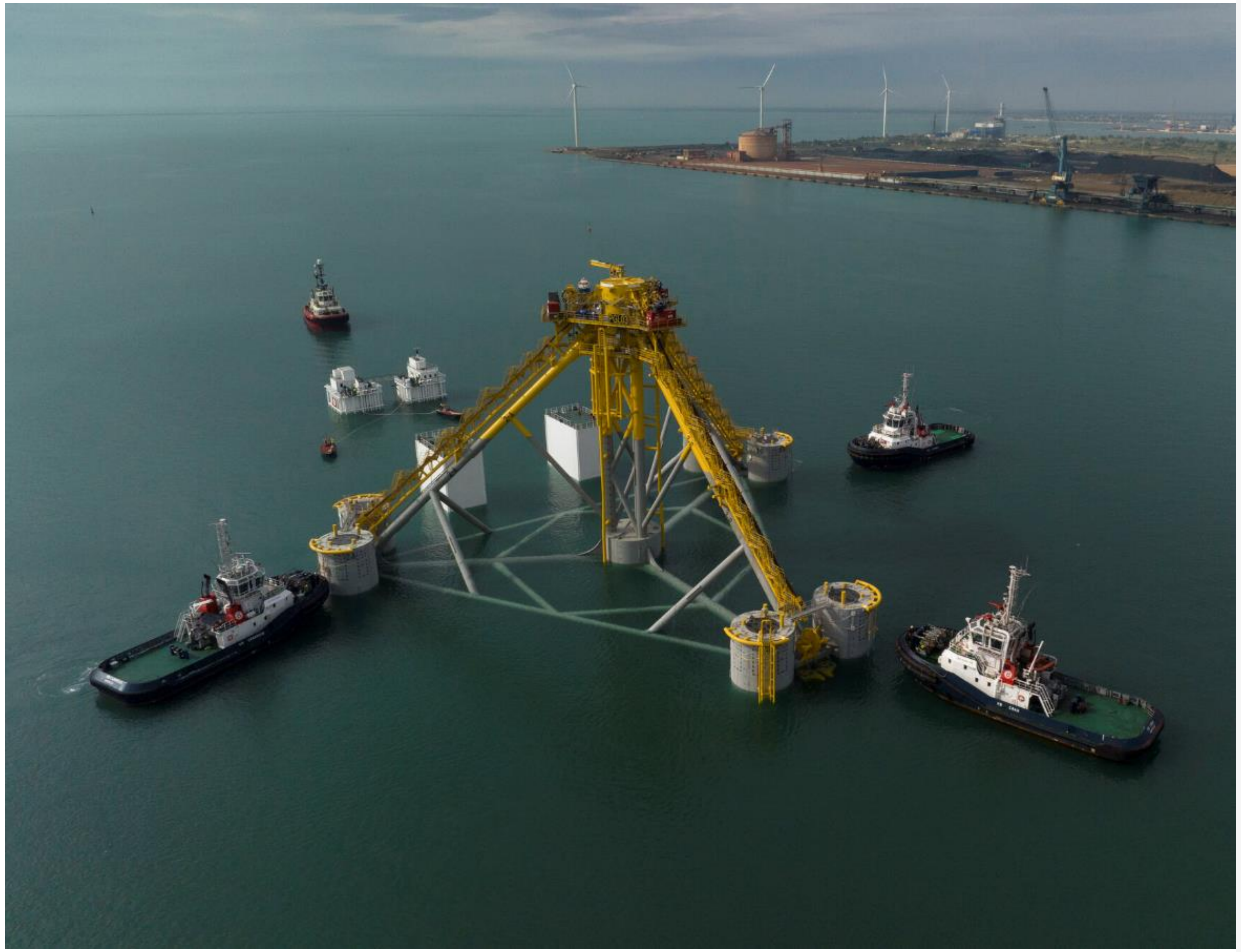
Agenda

- SBM's offering: F4W^{TM}
- What's necessary to design a FOWT ?
- Past experiences of floating wind designs with turbine OEMs
- Conclusions



F4W™ concept introduction

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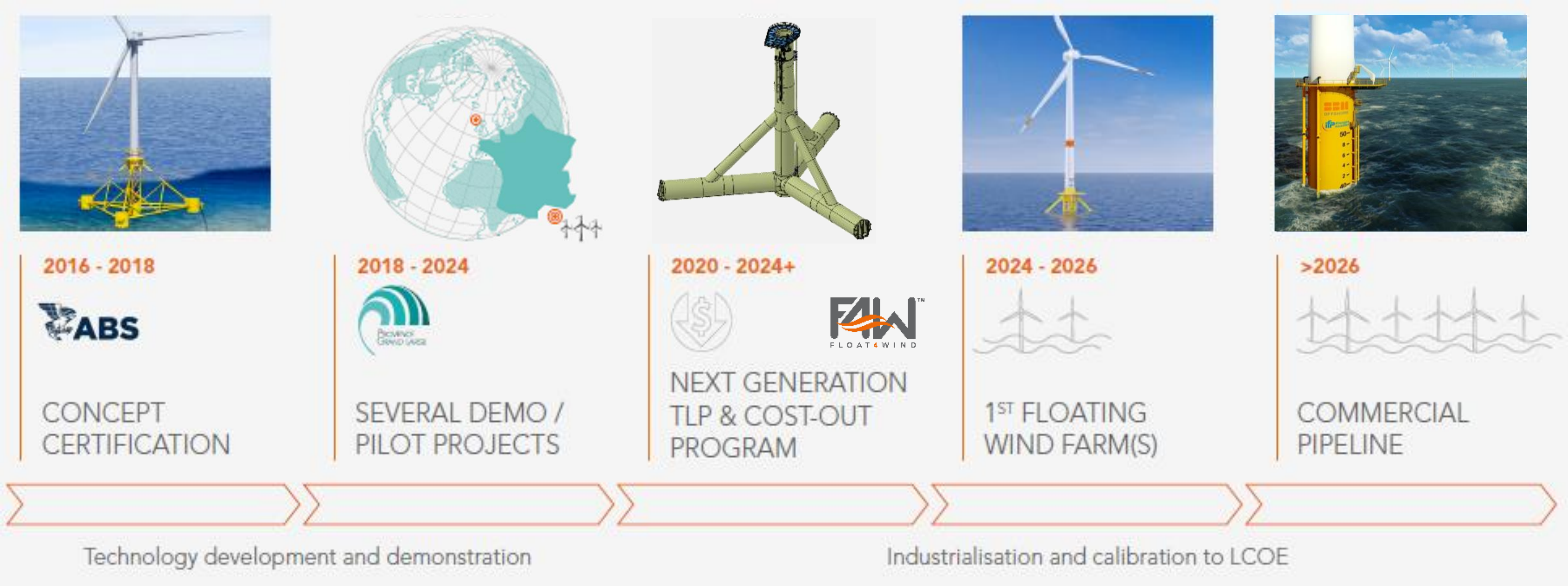
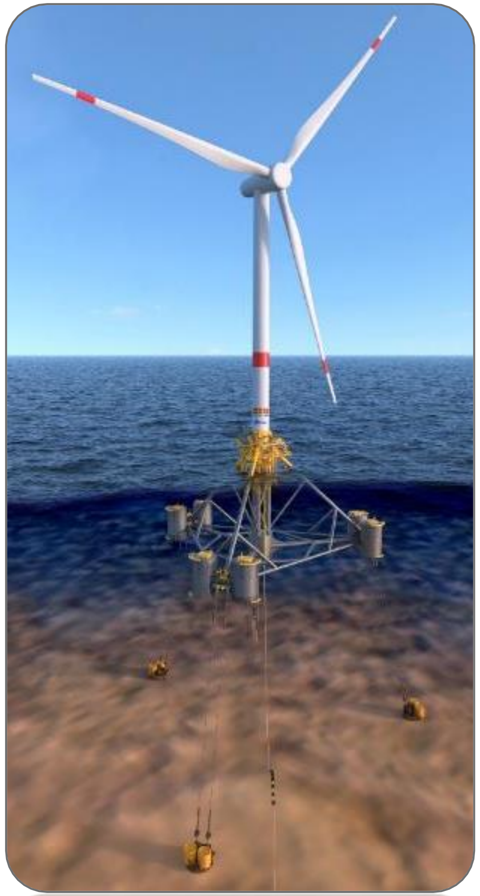
Our development Roadmap to take leader role

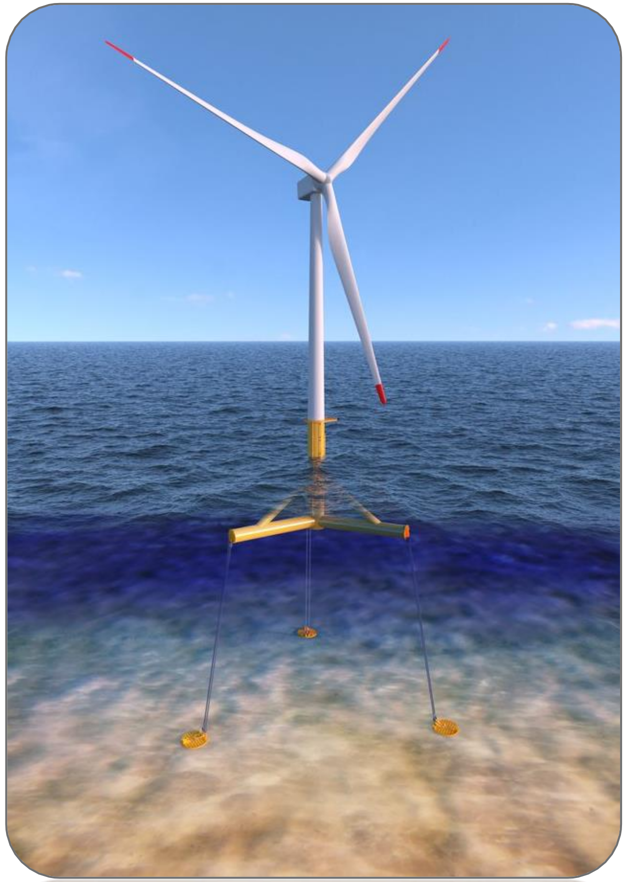


Design simplification

V1.0



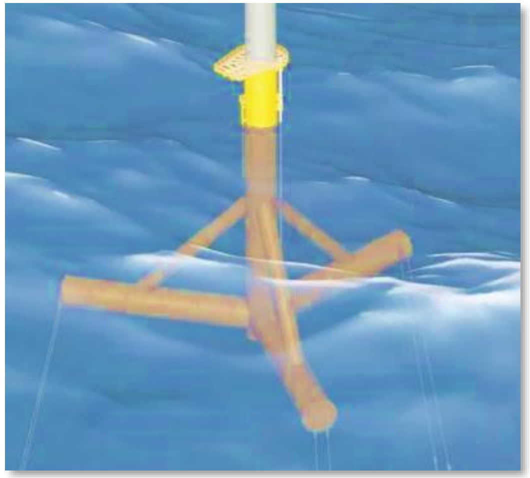
Design adaptation to series production

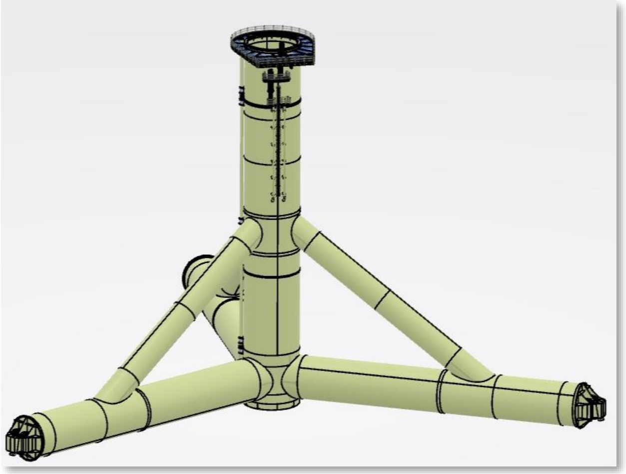


Design for in-place condition

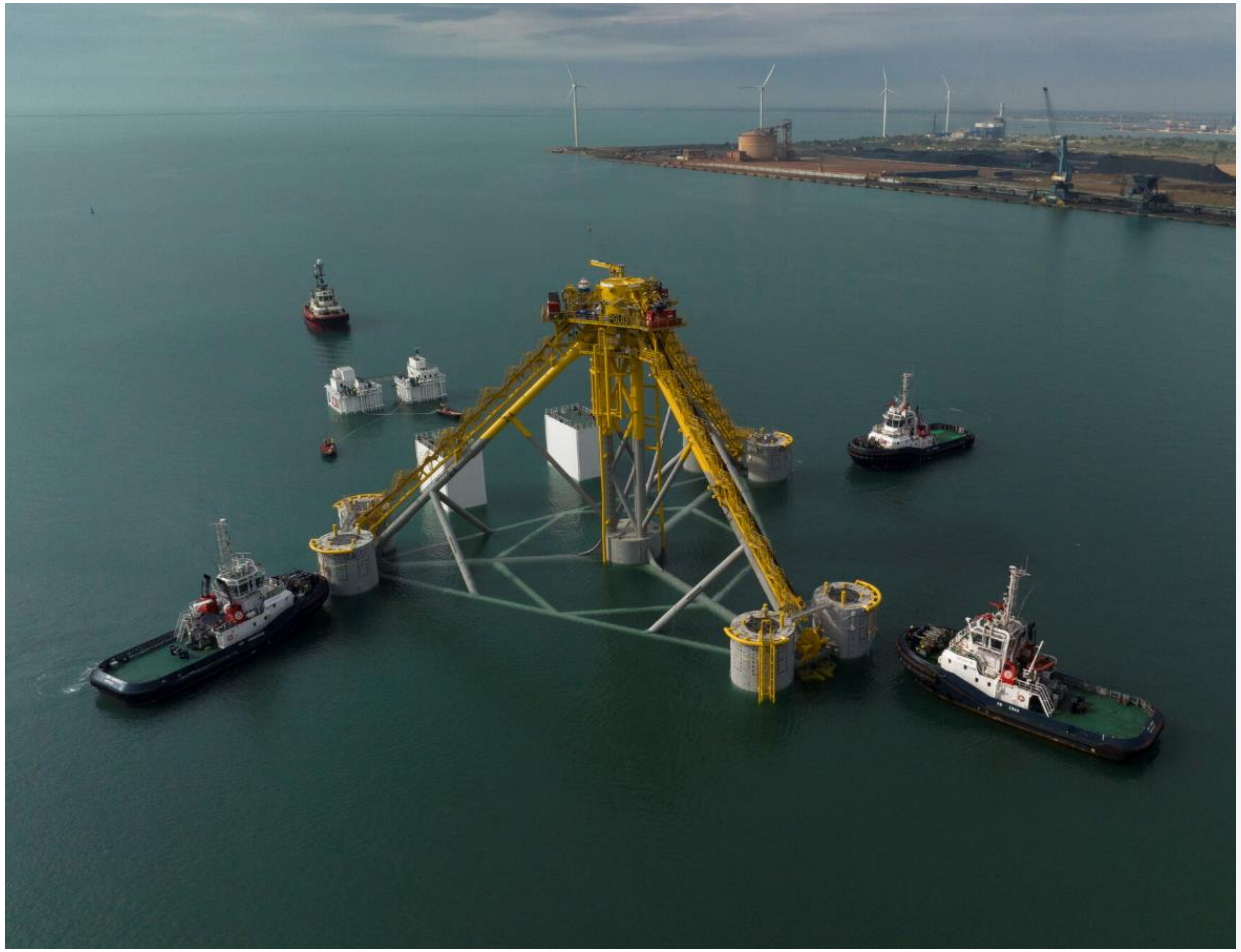
: a lean design

- Optimized TLP
  - Keep TLP benefits (low motion, small footprint…)
  - Drastic structural simplification
    - Removal of complex jacket type structures
    - Suppression of structural cast pieces
  - Structure solely designed for in-place requirements
  - Assembly of low-cost components (monopile from bottom-fixed industry)
  - Standard access similar to monopile
  - Transition Piece similar to bottom-fixed offshore wind





- Synthetic fiber rope moorings
  - Allows removing costly mechanical components
  - Reduces complexity and number of parts in mooring system
  - Reduces fatigue issues by removal of steel components



What’s necessary to design a FOWT?

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What's necessary for a floating wind design

- SBM's base offer is relative to EPCI of floaters, mooring and anchors, which means SBM's takes responsibility during such floating wind project execution

- From SBM's perspective:

- *Each party shall receive sufficient information from other project stakeholders in order to perform their own simulations and generate their own internal loads. This is the only way each party can engage guarantee / responsibility on their relative scope.*

- What is necessary for this ?
- Rely upon information:
  - Metocean data
  - Soil data
  - Turbine Model Data Package (MDP)

Turbine Model Data Package (MDP)

- Data package constituted in order to allow turbine back modelling with sufficient detail to generate accurate internal loading for the floating foundation (extreme / fatigue).

- Tower geometry / mass distribution
- Nacelle / Hub geometry & mass distribution
- Blade properties (weight and dimensions, structural, aero)
- Encrypted control system (with restriction of use to nominated users, or security with physical dongle with validity period)
- Benchmarking results (eigen frequencies, static, and dynamic both in production and parked)

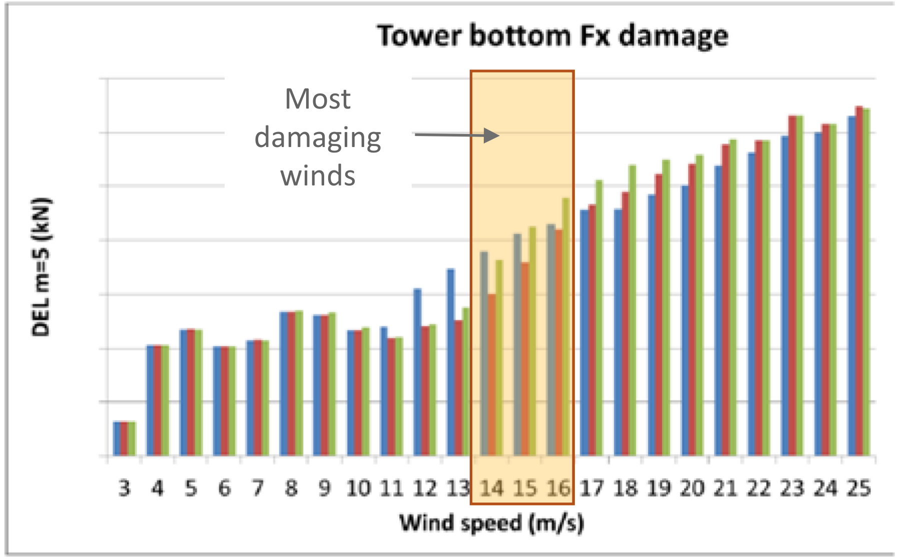
What if I can’t get this MDP ?

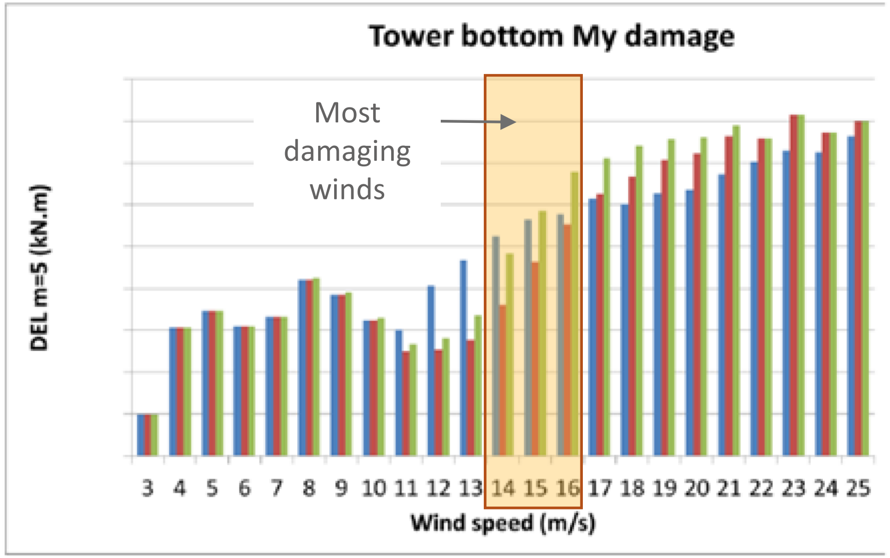
- On bottom fixed, most projects are executed with fully coupled simulations (Integrated Load Assessment ILA) being performed by the turbine OEM, based on design information received from foundation supplier
- On floating, some turbine OEMs try to replicate this and are reluctant in sharing this MDP with various said and unsaid reasons:
  - Fear of reverse engineering of control system
  - Keep dominant position on projects
  - Technical impossibility
  - Fear of being challenged by the results of a 2^{nd} coupled model to be run on projects

- From floater perspective, it is absolutely necessary to get this information to perform its own load assessment (to be reconciled with the one from turbine OEM)
- It is also necessary to perform simulations on WTG side with sufficient details on floaters

Can't you just create your own turbine model ?

- Some projects require floater designers to create their own turbine models, trying to replicate the selected turbine behavior for the project, by getting only dimensions, masses and time series of loads.
- This may be acceptable for early phases of projects, <u>but not acceptable as soon as binding commercial offers are to be made.</u>
- As an example:
  - Wrong blade properties → wrong blade eigen periods and overall loading
  - Wrong control system → wrong fatigue loading, impairing the fatigue design on the floater side
  - Imposing load time series received from turbine OEM in floater dynamic model → resulting fatigue loading on both floater and turbine side can underestimate the actual fatigue conditions





Control strategy 1

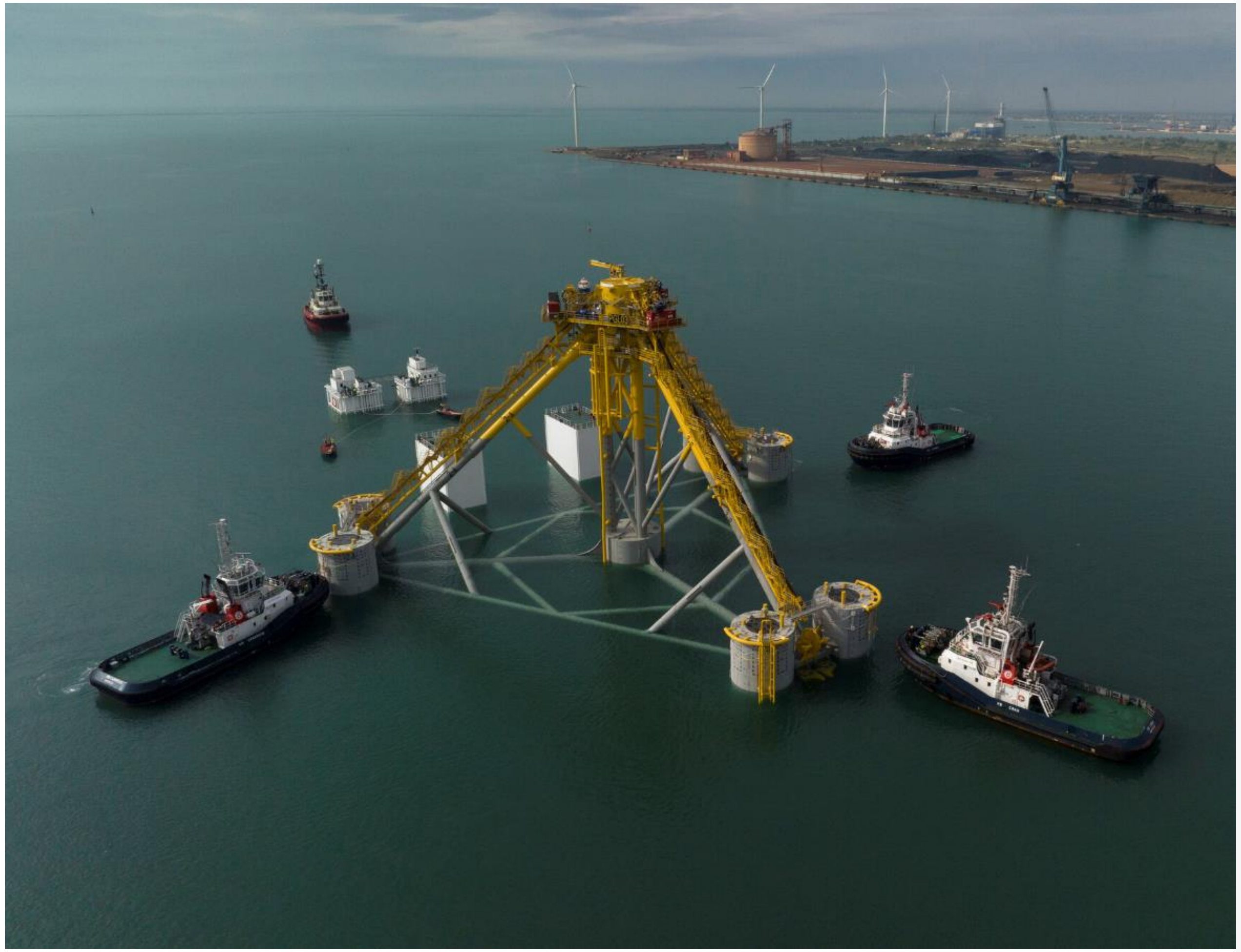
Control strategy 2

Control strategy 3

Large differences on DEL up to 40%
potential factor 5 on fatigue damage

Can’t we just have the turbine OEM doing the fully coupled calcs ?

- Set-up sometimes proposed on projects.
- A number of hurdles to overcome:
  - **Technical** :
    - Software compatibility, compatibility of internal automatic pre / post processing chains
    - Turbine OEM Software capability to reproduce floater behavior (different than bottom-fixed, model condensation techniques not applicable…)
    - Large volume of simulations to exchange (Terabytes)
  - **IP :** Similar to discussions on control system, there are specificities / model practices that SBM (and other floater designers) would not disclose to external party without counterparts.
  - Willingness of turbine OEM to generate all cases necessary for the validation of floater and mooring components, not impacting necessarily the turbine
  - In the end, if things come to worse, who is responsible ?
    - Turbine OEM in case of fatigue failure on floater, with fatigue loads underestimated in global model ?
    - Floater designer who did not do the global performance simulations but whose motions are too large and generated breakdowns on turbine ?
      - →Not possible for floater EPCI to reproduce / endorse calculations and guarantee floater on this basis
    - Developer takes all the risks ?



Past experiences of floating designs with turbine OEMs

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SBM / IFPEN Alliance

- Floating wind alliance built in 2015
- SBM is responsible for floater / mooring and anchor design
- IFPEN responsible for fully coupled simulations on projects and benchmark with external parties
- Execution of Provence Grand Large project with this set-up

SBM ambition: Find new markets related to core competencies

Strong knowledge in Business Development

Strong network in Industry, Institutions and Academia

IFPEN ambition: Find a partner to industrialize a floater solution

Floating and Mooring Systems Specialists

Coupled Approach of Floater and Wind Turbine

Ideal partnership to bring an optimal solution to the market started in 2015

SBM's past experience on coupled analyses

- Direct collaboration between SBM / IFPEN with 3 majors turbine OEMs
  - 6 to 16 MW machines
    - GE Haliade 150 – 6MW → Technology Development
    - SGRE 154 – 8.4 MW → Provence Grand large
    - GE Haliade-X → Joint internal development activities
    - Ming Yang 16MW → FEED project
- Collaboration included receiving full turbine MDP and back-modelling to run fully coupled analyses on SBM/IFPEN side
- No turbine controller adaptation required
- Robust AEP, leading to same energy generation than fixed turbines
- Limited number of iteration loops beween SBM/IFPEN and OEM to satisfy global performance requirements and limiting motion / acceleration envelopes

Workflow on projects

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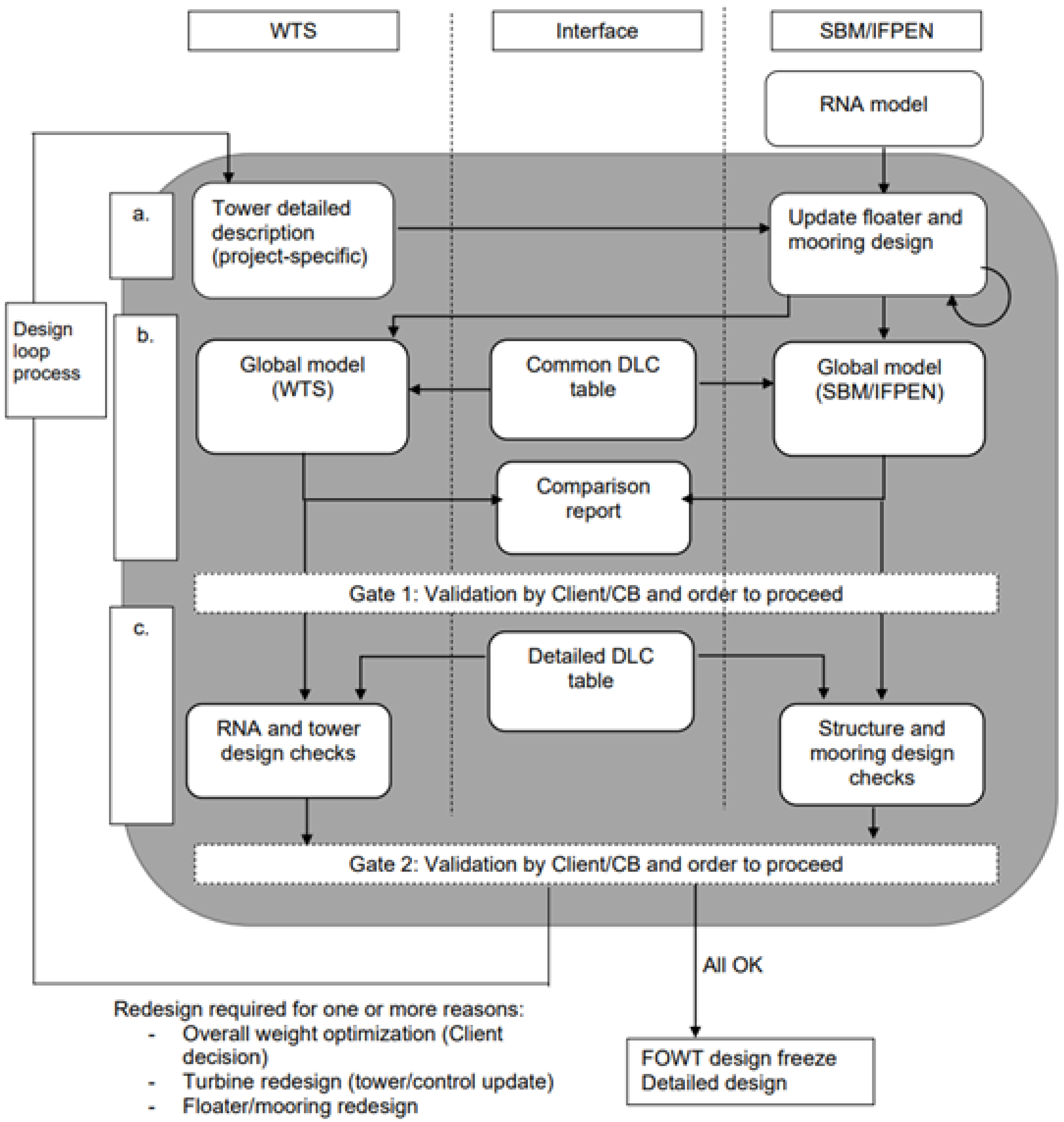
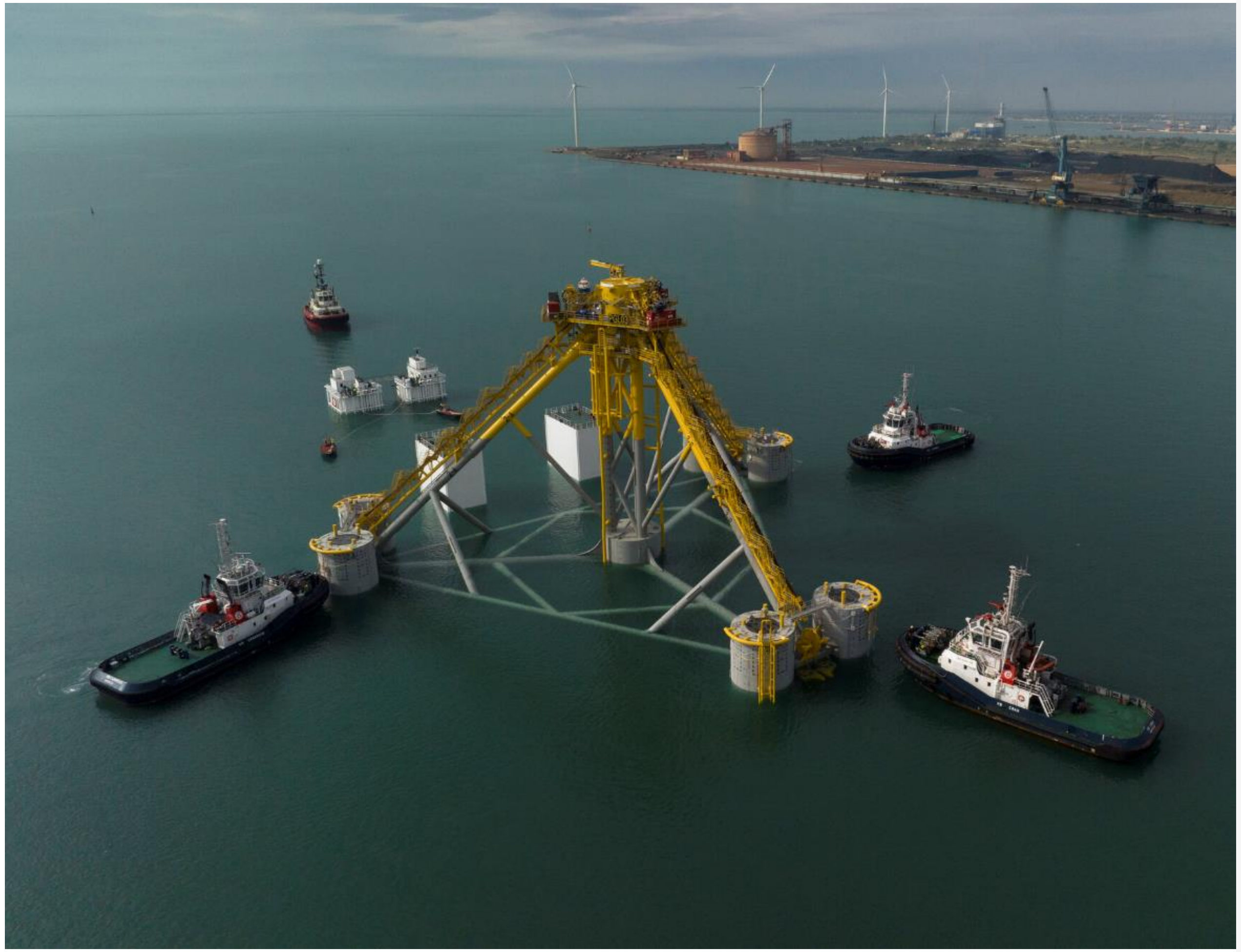
- Preliminary step: SBM/IFPEN back-model turbine, WTS back-models preliminary floater
- Step a: Initial floater design (SBM/IFPEN)
- Step b: Comparison of convergence of fully coupled models (SBM/IFPEN and WTS) on common DLC table
- Gate 1 : Models validated for full load assessment
- Step c: Full DLC table calculation and validation of all components (both turbine and mooring / floater / anchors)
- Gate 2: Validation and decision to run additional loop
  - Optimization or redesign





Conclusions

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- SBM offers next generation F4W^{TM} floating foundation to the market as an industrialized solution for floating wind deployment

- In SBM's view, a recognized EPCI company for floater delivery is key for success. As such, this EPCI shall have all means to guarantee design and execution to their end clients
  - → Performing fully coupled model on floater side is a necessary condition, as it is for wind turbines

- Previous experiences with this set-up have proved to be efficient and ensure quality of the engineering of the project in addition

TRUE.
BLUE.
TRANSITION.